Systems Driven Methodology & Tools

Experiences from the DOE CSP program

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Methodology

1) Understand current and future markets
2) Estimate the potential impact of the technology/market
3) Establish the current technology 'baseline'
4) Evaluate avenues for improvement
5) Decide how to allocate limited resources ($)
6) Repeat when conditions change
   - Markets or knowledge of markets
   - Knowledge of technology
   - Program resources change

1) Understand the Market(s)

- Identify important metrics (e.g. Levelized Energy Cost)
  - LEC not the one perfect metric, but probably the best
  - Incorporates initial cost, performance, O&M (incl. reliability), financial terms
- Value also important
  - Cost – Value (e.g. 5 c/kWh over competition)
  - Cost/Value (e.g. 25% over competition)
- Other requirements to deploy the technology?
  - Aesthetics, size, reliability, complexity, shipping, water use
- What is the competition? Is it penetrating the market?
  - Solar hot water, remote diesel

Market Analysis/Prediction Tools

- “Independent” analyses may have more credibility
  - Energy Information Agency (EIA)
  - Platts, other industrial sources
- Determine market ‘value’ targets
  - Utility scale: peak vs. off-peak value varies
  - Remote: market size = fcn(cost) … demand elasticity
  - Example: CSP Trough/Tower goal = 4-6 c/kWh
- Utility markets better defined than distributed, remote, residential markets

Calculating LEC

- Constant vs. current dollar analysis
- ‘Economic-level’ calculations

$$LEC = \frac{CC(\$) \times FCR + O\&M_{fixed}(\$)}{Annual\,Energy(kWh)} + \cancelto{0}{O\&M_{variable/fuel}(\$/kWh)}$$

- ‘Financial-level’ calculations
  - Cash flow analyses done for real projects
  - Can provide additional insights and accuracy
  - Incentive analysis for 1,000 MW initiative
  - Back out effective FCR from cash flow analyses
- Financial assumptions
  - Consistency important in evaluations
  - Typical values may vary with market segment

Cash Flow Model Schematic

Technology
Capital cost
Fixed O&M cost
Variable O&M/Fuel
Annual energy
Project lifetime

Taxes/Fees
Income tax
Property tax
Depreciation
ITC/PTC
Insurance

Inflation
Expenses
Energy revenue*

Annual Cash Flow
Optimizer
Minimizes LEC
** values adjustable within constraints*

Output Metrics
Current$ LEC
Constant$ LEC
Fixed Charge Rate
Etc.

Equity
IRR* (min)
Term

Debt 1
Rate
Term
Debt service ratio*
Reserve fund
Debt Ratio* (max)

Debt 2
…

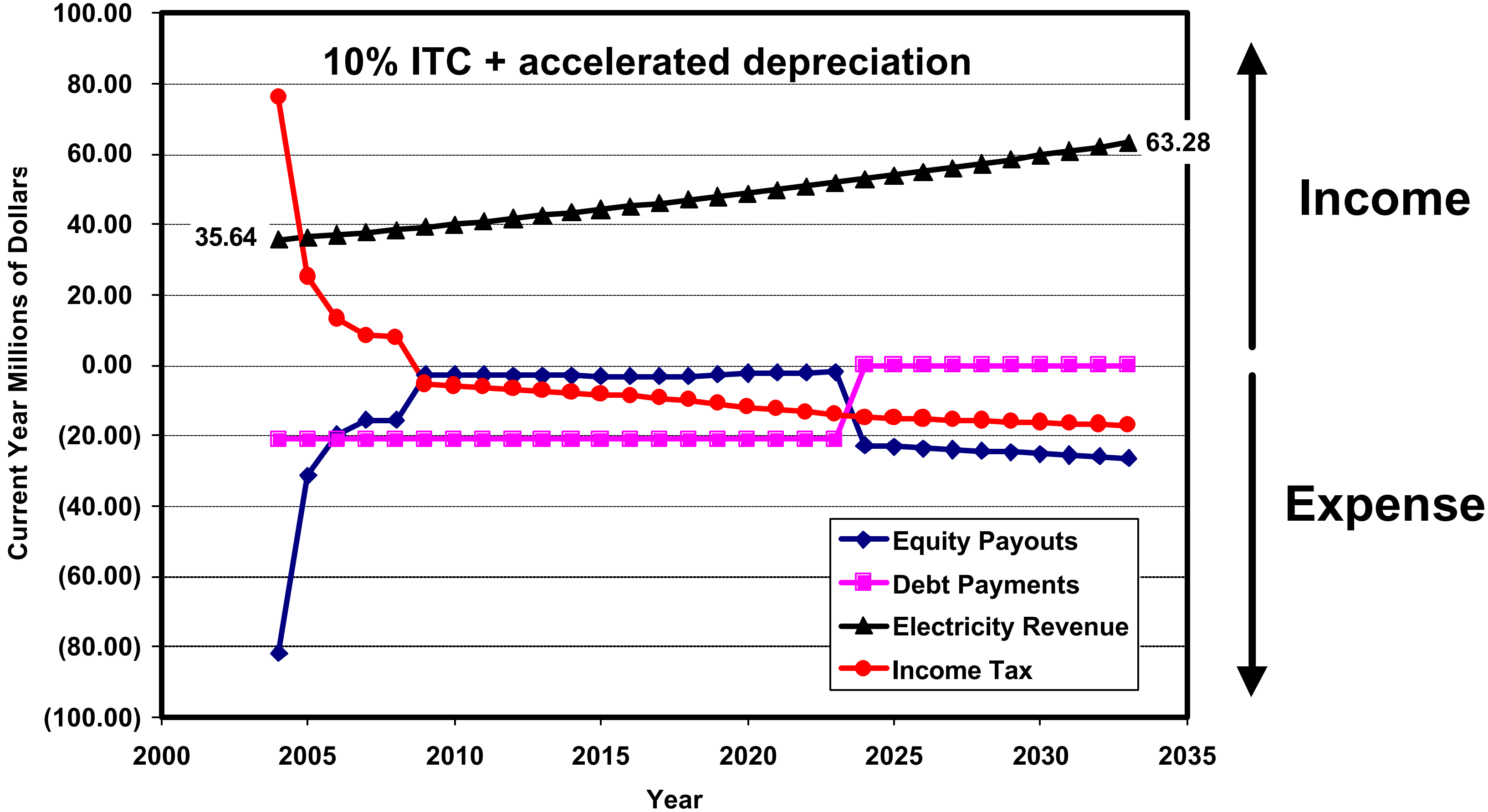
Debt 3
…

Example: Cash Flow Model Results

- CSP Power Tower Mid-Term Solar 100 plant
- CC = $311M, O&M = $0.005/kWh, Ann. Eff. = 16.5%
- Existing tax incentives: 10% ITC, accelerated depreciation

Selected Inputs	IPP Hi	IPP low	Corp Hi	Corp low
Debt Rate, Term	8%, 10-yr	8%, 10-yr	7%, 20-yr	7%, 20-yr
Minimum Equity IRR	18%	12%	18%	12%
Selected Outputs				
LEC (Current$/kWh)	0.088	0.065	0.063	0.049
Nominal FCR	16.1%	11.7%	11.1%	8.7%
LEC (2002$/kWh)	**0.070**	**0.049**	**0.048**	**0.037**
Real FCR	**12.5%**	**8.7%**	**8.4%**	**6.3%**
Optimal Debt Ratio	52%	44%	63%	61%

Example: Solar 100 Corp Hi



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2) Estimate the Potential Impact

- How big is the market?
- Maximum market share?
- What is the potential benefit to society?
  - Environment or Security
- Example: CSP benefits story
  - Vast, renewable resource exceeds global demand
  - Dispachability shaves peak periods, higher value
  - High CF permits high portfolio penetration
  - Able to make significant impact on global warming
  - Thermo-chemical options impact energy security

3) Establish Technology 'Baseline'

- Develop and validate models of the system
  - Performance
  - Cost
  - Component level & system level
  - Be realistic about the current status of the technology
    - E.g. SEGS experience tapped w/ O&M cost reduction project
  - Other metrics
    - Dish reliability database
    - Some metrics hard to quantify (e.g. aesthetics, complexity)

Technology models

- One model probably impractical for handling even a single technology
- Subsystem Physical models
  - Receiver thermal and mechanical behavior
  - Power cycle thermodynamics steady state and transient
  - Optical performance/optimization
- Annual system performance
  - Uses physical model result input (e.g efficiency)
  - Off-design operation: startup, shutdown, part-load, offline
  - Impact of variable resources, siting
- Installed Cost Models
- Financial models

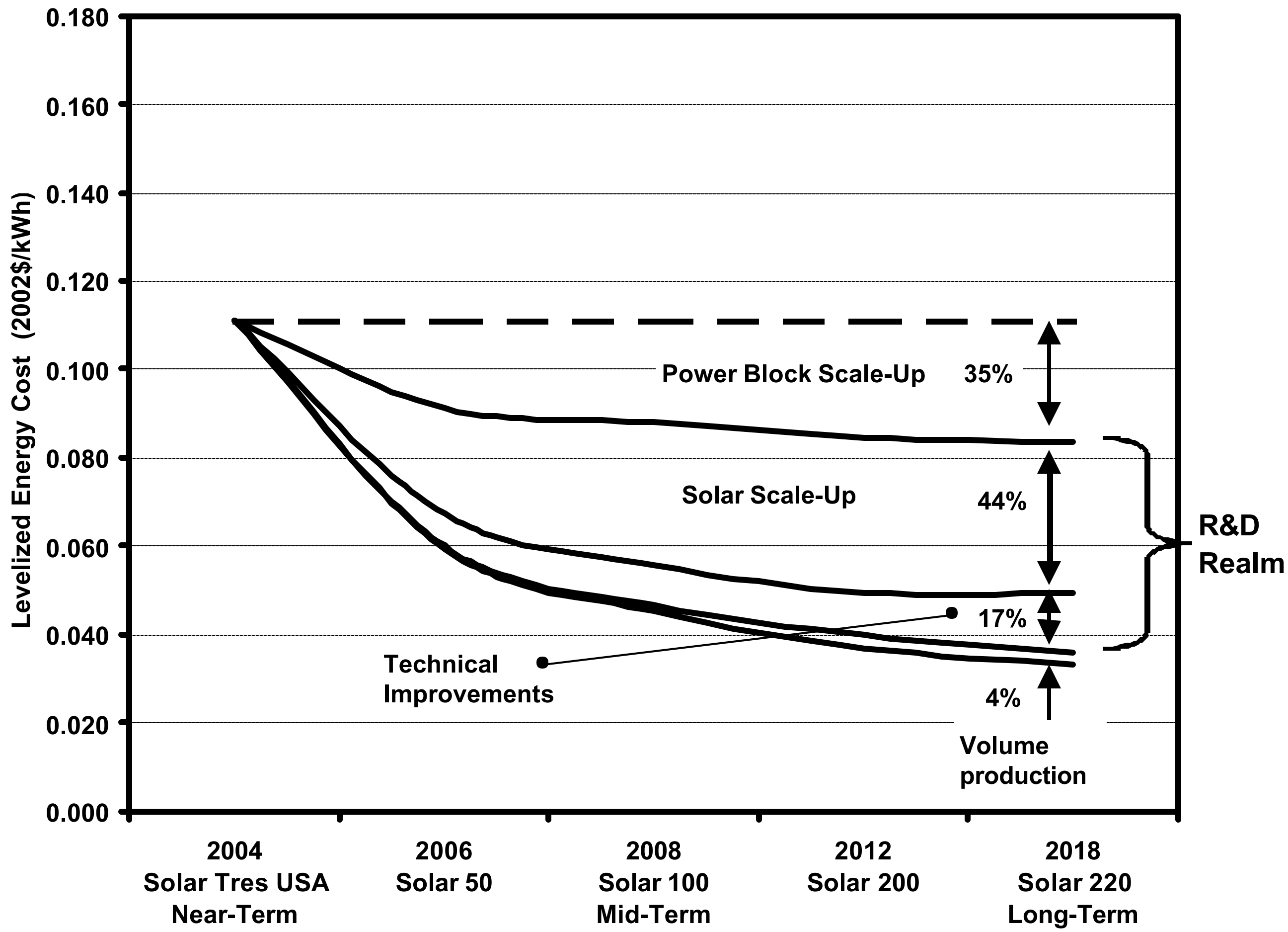
Cost Models

- Cost sometimes proprietary. Price often easier to get.
  - Costs are location and time dependent (+/- 20%)
  - Avoid attributing technology trends to this variability
  - Identify commodity and custom parts
  - Get vendor quotes if possible. Benchmark against other products.
  - Use care in projecting impact of volume production (e.g. learning curves)
- Other costs
  - Project development costs, insurance, etc.
  - Infrastructure (e.g. T&D)
  - Contingencies
  - Shipping
  - Profit

4) Evaluate Avenues for Improvement

- Consider all aspects (capital cost, O&M, performance, financial)
  - E.g. tax equity
  - Incremental and substantial changes
- Parametric studies on avenues for improvement
  - Isolate impact of each change on baseline system metrics
  - Caution: impacts (%LEC reduction) on baseline may not be additive
- Technology roadmap showing system evolution including effects of multiple changes

Example: Tower LEC by Category



- Learned new things
- Scale-up largest effect
- Huge heliostat production volume not necessary

5) Decide how to allocate limited resources ($)

- Analyze cost/benefit/risk tradeoffs
  - Estimate risk, use judgment in decision making
  - Statistical tools helpful, can't replace judgment
- 'Low-hanging fruit' + long-term goals
- High risk, high payoff sometimes appropriate
- Consider roles of industry, labs, etc.
- Technology demonstration (risk reduction) important in the commercialization process
- Develop Technology roadmaps + RD&D plans
  - Set milestones

Summary

- Poor models or poor input data = poor results
- Consistency of assumptions or optimism
  - Labor rates (e.g. $30/hr for power plant O&M, $60/hr for residential service call)
  - Materials costs (commodity vs. custom parts)
  - Financial Terms
- Addressing uncertainty
  - Scenario analysis (low, medium, high)
  - Quantify uncertainty of every input (not likely)
  - Acknowledge differences in prediction accuracy
    - Current vs. distant future
    - Learning curves, validated scaling factors, vendor quotes
    - R&D risk fundamental or applied